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CANADA'S HYDROGEN AND FUEL CELL INDUSTRY

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CLEAN POWER FOR THE
21st CENTURY



Natural Resources
Canada

Ressources naturelles
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Canada

At the beginning of the new millennium, climate change, energy security and sustainable development of our natural resources are issues at the forefront of many people's minds. Key solutions to these challenges include diversifying our energy sources, using energy more efficiently and adoption of alternative fuels. Natural Resources Canada has been involved in the R&D of alternative transportation fuels such as hydrogen and fuel cells for more than 15 years. During that time a strong partnership between government and industry has been brokered, and we are working together to bring world-leading technologies to market.

A recent showing of government support is the new National Fuel Cell Research and Innovation Initiative, a \$30 million commitment going toward the establishment of a Fuel Cell Testing and Demonstration Facility at the Innovation Centre in Vancouver, an R&D and deployment program, and a university research fund for fuel cells. Investments like this initiative not only further the development of fuel cell technologies but also demonstrate the extent to which the government believes that fuel cells are a viable energy option.

There will be many opportunities for hydrogen and fuel cell use in the coming years. Transportation is an obvious opportunity, with a zero emission fuel cycle as the goal. Other opportunities include remote and portable power, and fuel cells for residential and stationary power generation.

During the past few years, hydrogen and fuel cell technologies have been maturing at a very rapid rate. A whole industry, committed to providing cleaner transportation and stationary power systems, is emerging and Canadian technologies are at the forefront of this new and exciting field. With fuel cell powered vehicles close to becoming a commercial reality, the proper infrastructure must be put in place to receive these vehicles. As Canada's evolution into a world-class leader in hydrogen technologies has shown us, much is possible now and in the future. Some of Canada's key players in the area of hydrogen and fuel cells are noted in this brochure.



Agile Systems Inc.

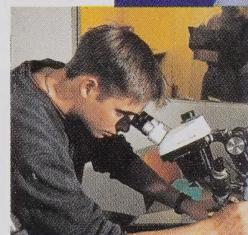
Agile Systems designs and manufactures power and control electronics for the fuel cell, automotive, automation and robotics industries. Agile uniquely has the breadth of industrial design and manufacturing knowledge to deliver a low-cost, high-performance, commercial-quality electronics module that satisfies a fuel cell application's varied requirements.

Agile's firmware driven design results in a flexible unit that is distinct in the marketplace and protects each client's intellectual property. The company's extensive industry experience includes: advanced battery management; sine wave inverter designs from 100W to over 30kW; variable-speed AC motor control including brushless, sensorless motors; DC-DC converters; configurable display including state of charge; accessory DC power; electro-proportional valve control; high-frequency data sampling and inter-module network communications. Agile's patented manufacturing technology means its intelligent power modules provide maximum power, control and communication functionality.

Armstrong Monitoring Corporation

Armstrong Monitoring, an ISO/9001 registered manufacturer of high-quality gas-sensing apparatus, prides itself in meeting the needs of the fuel cell and hydrogen industries. In the 20 years since its inception, Armstrong has been involved in research, design and commercialization of innovative new technologies and products for a wide-range of industries and applications.

Armstrong's diverse product line features hazardous gas monitoring equipment ranging from simple, building block sensor elements and transmitters, to complete, integrated turnkey systems. Working in concert with Canada's leading research organizations, Armstrong brings together the science, technology and marketing required in today's knowledge-based economy, at home and around the world.



Ballard Power Systems

Ballard is the world-leader in the development and commercialization of proton exchange membrane (PEM) fuel cells. Fuel cells are widely viewed as viable alternatives to conventional power technologies. Through strategic alliances with global leaders in targeted markets, Ballard combines technology leadership in fuel cells and fuel cell systems with the product engineering, manufacturing, marketing, distribution, and service capabilities of its strategic partners. This allows Ballard to advance deliberately and with reduced risk. Ballard is focussed on building solid customer relationships and developing competitive products that will assist customers in meeting their objectives.

Soon, Ballard® fuel cells will provide efficient, clean power where people need it most. Buses, automobiles and trucks will provide the performance people expect without today's level of pollution. Distributed power plants will provide high-quality, reliable electricity without adding new high-voltage transmission lines and central generating plants. Portable power systems will provide the flexibility we require without noisy generators or bulky batteries.

Bureau de normalisation du Québec

The Bureau de normalisation du Québec (BNQ) is the standards development organization that has assumed the responsibility for the Secretariat of ISO Technical Committee TC 197 *Hydrogen Technologies* since 1994. This responsibility, assumed by BNQ on behalf of the Standards Council of Canada, has enabled Canada, and more specifically Canada's hydrogen industry, to take an active part in the standardization of hydrogen technologies.

ISO/TC 197 is one of 200 technical committees of the International Organization for Standardization (ISO). It was created in 1990 to develop international standards in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. The ISO/TC 197 mission is to provide global leadership in the development and understanding of standards on hydrogen technologies with a view to facilitating the introduction of these emerging technologies to the market.

Cellex Power Products Inc.

Cellex Power Products is a leading developer of fuel cell-based power products for use in premium power applications. Cellex Power combines its proprietary components and integration technology with the best of breed of fuel cell hardware supplied by leading vendors to deliver complete and profitable power solutions to customers. Cellex Power was founded in 1997 and is based in Vancouver, BC.

The Canadian Hydrogen Association

The Canadian Hydrogen Association (CHA) is a non-profit membership association composed of universities, research organizations, industry and small businesses. The objective of CHA is to promote the use and development of hydrogen energy, hydrogen energy systems and technologies including fuel cells and to develop the role of hydrogen energy for the purpose of improving the environment.

Besides having mini workshops on topics of interest to the hydrogen community, CHA holds annual meetings in different regions of Canada.

Centre for Hydrogen and Electrochemical Studies

The Centre for Hydrogen and Electrochemical Studies (CHES) has served to bring together those researchers at the University of Toronto working in hydrogen and electrochemical studies and a diverse range of related materials, energy and environmental technologies, all of which are integral to the emerging hydrogen economy. Specific areas of expertise include electrolysis, fuel cells, sensors, nanotechnology, materials, combustion, and hydrogen infrastructure systems.

CHES researchers have established links with colleagues at both the Institute for Integrated Systems (IESVic) at the University of Victoria and the Institut de recherche sur l'hydrogène at the Université du Québec à Trois-Rivières. CHES, working with the Canadian Hydrogen Association and various government agencies - particularly Natural Resources Canada - has active links with numerous industries.

Dynetek Industries Ltd.

Dynetek Industries is a market-leader in Advanced Lightweight Fuel Storage Systems™ for compressed natural gas (CNG) for low-emission CNG vehicles and compressed hydrogen for zero-emission hydrogen fuel cell vehicles. The Dynetek fuel storage system is marketed under the DyneCell® brand name. DyneCells are made with a seamless thin-wall aluminum liner with a full carbon fibre overwrap. The liner technology provides ultra lightweight, high-storage capacity and non-permeability, while the corrosion resistant overwrap maximizes strength-to-weight ratios and optimal performance under harsh automotive conditions.

Applications consist of passenger vehicles, heavy- and light-duty trucks, shuttle buses and transit buses. Dynetek's customers include Ballard Power Systems, XCELLSIS, Ford, Nissan, MAN Technologie (Germany), and New Flyer (USA). Benefits of using DyneCells include extended vehicle range, increased payload capacity and enhanced vehicle performance. DyneCells are certified in 11 countries.



Fuel Cell Technologies Corporation

Fuel Cell Technologies (FCT) is an advanced fuel cell power source system integrator. FCT's core business is the production of small-scale solid oxide fuel cell (SOFC) power systems to provide electricity and heat for stationary applications such as homes, remote sites and small commercial enterprises. The company also continues to produce aluminum air power systems for unmanned underwater vehicles and remote communications installations.

FCT's core competency is in the designing and building of complete power systems, particularly the complex engineering of the components and controls - called the balance of plant - that surround the cell stack. By combining our expertise with the mature SOFC technologies from world-leaders, risk, cost and time to bring a commercial SOFC power system to market are reduced.



FuelMaker Corporation

FuelMaker is known as the world-leader in supplying compact, flexible systems for refuelling vehicles with natural gas. While several companies are developing hydrogen fuel cells, there has not yet been a clear solution to the hydrogen infrastructure problem. That is where FuelMaker comes in. FuelMaker has the only small-scale, economical, fuelling technology capable of compressing hydrogen or natural gas to 5,000 psi. Its systems will be able to deliver the fuel in a distributed energy infrastructure, supplying hydrogen or natural gas to virtually any home or factory anywhere. FuelMaker is currently working with several companies to make refinements to the hydrogen drying and compression equipment, and is also working on high speed, high flow dispensing systems for hydrogen.



The company has built its expertise by refuelling natural gas vehicles in commercial and residential applications around the world. FuelMaker has also developed the safety devices, connectors, accessories, software and the compression systems that make a distributed gas infrastructure feasible.

GFI Control Systems Inc.

GFI Control Systems is a leading Canadian company engaged in the research and development, production and marketing of advanced fuel metering systems and components for hydrogen, compressed natural gas, and propane-powered vehicles. As the first alternative fuels company to be QS 9000 registered, GFI is a leading supplier worldwide of components to automotive Original Equipment Manufacturers involved in compressed hydrogen storage for fuel cell vehicles and power generation systems. These patented components include pressure regulators, tank valves, and pressure relief devices. GFI's components can be found on each of the vehicles powered by high-pressure hydrogen involved in the California Fuel Cell Partnership.

As part of its ongoing commitment to increasing the technology of hydrogen components, GFI is currently working on a significant prototype program with Dynetek for the supply of 5,000 psig components, including an in-tank tank valve/regulator.

Global Thermoelectric

Since 1998, Global Thermoelectric has spearheaded the development of planar (flat) solid oxide fuel cell (SOFC) technology. Today, in part, as a result of Global's technical successes, SOFCs are emerging as a competitive alternative to other fuel cells. The SOFC's principal advantages, namely elevated operating temperatures (600°C to 800°C) and ceramic construction, make SOFCs easier to operate with hydrocarbon fuels and more efficient and effective for combined heat and power applications.

Global develops fuel cell stacks for automotive and stationary applications, and has secured a key strategic partner in Enbridge Inc. to distribute residential and light industrial natural gas fuelled SOFC systems in Canada. The company expects to begin distributing fuel cell systems to niche stationary markets in late 2002. Customers needing power in remote locations will likely be amongst the first users of fuel cells.



H Power Enterprises of Canada Inc.

H Power Enterprises of Canada is a subsidiary of H Power Corporation. H Power Enterprises is a leading fuel cell development company and one of the first providers to complete a commercial sale of a proton exchange membrane (PEM) fuel cell system. PEM fuel cells generate electricity efficiently and cleanly from the electrochemical reaction of hydrogen and oxygen.

Hydrogen is typically derived from conventional fuels such as natural gas or propane, and oxygen is drawn from the air. H Power's fuel cells are designed to provide electricity for a wide range of stationary, portable and mobile applications including residential cogeneration products for rural, remote homes, and back-up power units for mobile applications. In August 1999, the company entered into a ten-year agreement with ECO Fuel Cells, LLC, a subsidiary of Energy Co-Opportunity Inc. (ECO), to market, sell, install and service stationary power fuel cell systems. ECO is an association of approximately 200 U.S. rural electric cooperatives.

Hydrogen Systems Inc.

Hydrogen Systems is a global hydrogen solutions supplier with operating units in North America, Europe and Asia. The company produces and distributes a new generation of alkaline membrane-based hydrogen generators. With its international network, Hydrogen Systems is ready to respond quickly to the needs of its clients anywhere in the world.

Hydrogen Systems' extensive range of Inorganic Membrane Electrolysis Technology® (IMET) generators replaces conventional hydrogen supply systems with on-site and on-demand hydrogen production, thus eliminating the need for costly distribution and storage. What's more, this innovative technology provides users with the best energy efficiency in the industry. IMET generators require the lowest amount of kWh per normal cubic meter of hydrogen produced and deliver hydrogen at the desired utilization pressure. This revolutionary technology is already in use in several key industrial sectors. Hydrogen Systems is also aggressively pursuing research to develop new cutting-edge hydrogen technologies aimed at industrial and commercial markets around the world.



Hydrogenics Corporation

Founded in 1995, Hydrogenics develops and commercializes proton exchange membrane (PEM) fuel cell power generators, including associated fuel cell test and control systems and related products. The company recently expanded its production and R&D capabilities by relocating to a 95,000ft² facility in Mississauga, Ontario.

Building on the company's core competency of fuel cell system integration, its first commercial product line was the FCATS series of automated fuel cell test and control systems. These systems are now operating on location for several marquee customers, including major automotive manufacturers. Hydrogenics is also developing fuel cell power generators. One such product is a fuel cell power generator designed with sub-zero temperature capabilities, built around Hydrogenics' proprietary ambient-air fuel cell stack. The latest generation of this product will be demonstrated in an Antarctic application. Hydrogenics has recently demonstrated a portable multi-kilowatt fuel cell power generator with a metal hydride hydrogen supply under contract with National Defence Canada.

Hydro-Québec

For over 30 years, Hydro-Québec has conducted R&D and testing in the fields of fuel cells and hydrogen technologies through its Research Institute (IREQ). Hydro-Québec is focussing its R&D efforts on electricity generation, transmission and distribution. Areas of concern include the emergence of decentralized electricity generation and the impact these technologies will have on the supply of electricity to Hydro-Québec's customers. Various technical and economic models and analyses have been developed to quantify the risks and opportunities (including fuel cells) of decentralized electricity generation on both the operations of an electric utility, such as Hydro-Québec, and its customers.

In the area of hydrogen technologies, R&D efforts in recent years have focussed on the development of materials and systems for storage of hydrogen in metal hydrides produced by high-energy mechanical milling. Hydro-Québec, through its venture capital unit (HQ Capitech), has invested directly in various companies active in the fuel cell sector including H Power and Metallic Power, among others.



Institute for Integrated Energy Systems

The Institute for Integrated Energy Systems at the University of Victoria (IESVic) promotes feasible paths to sustainable energy systems by developing new technologies and perspectives to overcome barriers to the widespread adoption of sustainable energy. Founded in 1989, IESVic conducts original research to develop key technologies for sustainable energy systems and actively promotes the development of sensible, clean energy alternatives.

Proton exchange membrane (PEM) fuel cell research includes high power density stack design, failure diagnostics, computational modelling of operation and design for manufacturing. Research in biotechnology explores hydrogen production and fuel processing. In addition to research, members of IESVic are committed to providing service in support of other groups developing sustainable energy, education about energy and fuel cells at all levels, and communicating the vision for hydrogen and clean energy wherever possible.

The Institut de recherche sur l'hydrogène

The Institut de recherche sur l'hydrogène (IRH) is a research unit of the Université du Québec à Trois-Rivières. The research interests of the IRH are diverse and extend from the fundamental to the applied. Its research activities are mainly geared towards the use of hydrogen as the energy vector, especially in the areas of storage, transport, safety and use.



The IRH has developed a lasting partnership with Canadian industry. It responds to the diverse interests and goals of its partners by identifying and solving problems, as well as providing the expertise and facilities to evaluate new technologies. The IRH is a member of the Canadian Hydrogen Association and the National Hydrogen Association. It is closely associated with the International Standard Organization - ISO/TC 197 for hydrogen technologies.

Kinectrics Inc.

Kinectrics, a Canadian energy sector services company, is constructing and operating the world's largest pre-commercial solid oxide fuel cell (SOFC) combined heat and electric power plant. Ontario Power Generation, the Government of Canada, Siemens Westinghouse Power Corporation and the U.S. Department of Energy are cooperatively funding the \$18 million project.

A SOFC uses a fuel such as natural gas to produce electric power by an electrochemical reaction, thereby avoiding the air pollutants and inefficiency associated with traditional combustion processes. Energy efficiency is more than doubled when compared with traditional coal-fired power generation and distribution because it can be located where the energy is needed. The SOFC system is expected to be relatively quiet, highly reliable and simple to operate, with low operating and maintenance costs. It will be capable of using alternative fuels such as propane and diesel. The system's modular design allows sizing to satisfy a wide range of applications - residential, commercial and industrial.

Kraus Group Inc.

Kraus Group is a designer and manufacturer of integrated refuelling station technologies for the global alternative fuels market, specializing in compressed natural gas, propane and compressed hydrogen fuels. Kraus equipment is helping to clean the air around the globe, from Beijing and Cairo to Los Angeles and Mexico City, in applications ranging from small school districts and taxi fleets to the largest public transit operations in the world.

As fuel cells lead the new wave of change in the transportation industry, Kraus is leading the way in the development of the required refuelling technologies. Kraus' innovative hydrogen refuelling station design accommodates multiple sources of hydrogen, including on-site reformation of natural gas or electrolysis, or delivery of industrial hydrogen, and optimizes the utilization of ground storage for reduced overall system cost. Kraus also offers a line of contemporary "retail-style" hydrogen dispensers specially designed for public refuelling applications, the first of their kind in the world.



McGill University

Since 1990, researchers at McGill University have pioneered the development of a new kind of hydrogen storage system: catalyzed, nanocrystalline metal hydrides. These materials can store and release hydrogen at ambient pressure in the temperature range (depending on type) from room temperature to 300°C. The hydrides developed by McGill also include a new ultra-lightweight alloy that has the highest capacity by weight of any known hydride storage system: 9 wt.%. In developing these new systems, McGill researchers have focussed on using low-cost materials and simple fabrication methods that may be directly scaled-up to industrial production levels.

With their low-cost, enhanced performance, wide range of operating parameters and high safety factor, these materials are set to become the medium of choice for most hydrogen storage applications.



Powertech Labs Inc.

Powertech Labs is an ISO/ 9001 registered company. It is a wholly-owned subsidiary of the B.C. Hydro and Power Authority, a Crown Corporation of the British Columbia Government. B.C. Hydro is a world leader in promoting the production of hydrogen through electrolysis. Together with B.C. Hydro, Powertech Labs is establishing a 70 MPa (10,000 psi) hydrogen filling station infrastructure in the Vancouver area for the operation of fuel cell and hydrogen internal combustion demonstration vehicles.



The Gas Systems Group at Powertech is applying its experience in evaluating compressed gas storage and valve technologies to develop standards for compressed hydrogen systems. The Gas Systems Group provides the convenership to the ISO/ TC 197 working group developing the hydrogen tank standard (ISO/ 15869), and is investigating the performance of ultra high pressure hydrogen tanks exposed to various service conditions, including bonfire, gunfire, permeation, hydrogen pressure cycling, etc. In addition, verification tests are conducted on Original Equipment Manufacturers hydrogen storage systems.

QuestAir Technologies Inc.

QuestAir Technologies is the world leader in ultra-compact, pressure swing adsorption (PSA) based gas separators and purifiers. QuestAir is developing and commercializing PSA systems that separate and enrich oxygen and hydrogen containing gas streams. The company is manufacturing and selling its first generation hydrogen purification PSA system ("HyQuestor") to industrial gas, refinery, and fuel cell refuelling station users. An enhanced process cycle reduces the package footprint by 75% of the equivalent capacity, compared to conventional PSA systems.

QuestAir is developing several versions of its second generation, fast cycle, and compact PSA technology. The oxygen enrichment systems cover applications in mobile and stationary fuel cells. The compact hydrogen development is directed at clean-up/purification systems for vehicles and stationary fuel cells. QuestAir's compact technology provides enriched hydrogen and oxygen feeds, thus improving fuel cell performance.

Stuart Energy Systems

Stuart Energy has over 50 years of experience in manufacturing hydrogen-producing equipment. Recent advances in Stuart's proprietary technology have allowed the company to expand its scope to include larger industrial hydrogen markets, regenerative power and transportation markets. The Stuart Fuel Appliances use only electricity and water to produce high quality hydrogen. When the electricity is generated from renewable sources such as wind or solar, the entire process from fuel production to consumption in a fuel cell is zero emission.

Stuart is currently developing a complete line of products including: the Community Fueler, a unit ideally situated at the corner lot or at fleet sites; the Bus Fueler, designed to meet the needs of an expanding hydrogen bus fleet (currently being demonstrated at SunLine Transit in California and demonstrated at a recently completed project at Coast Mountain Transit, in British Columbia); and the Personal Fuel Appliance, a prototype developed for use at the family home, providing the ultimate in distributed and convenient hydrogen.



Hydrogen and Fuel Cell Activities



TISEC Inc.

TISEC is a Montreal based engineering firm, providing specialist services in reliability engineering, infrastructure inspection, non-destructive testing, code conformity assessment and quality system development. TISEC has unique expertise and experience in safety, risk and reliability technologies applied to hydrogen systems. This expertise includes design and analysis of new facilities for the storage, transportation and use of hydrogen, as well as addressing issues such as component and system selection, site location requirements, code compliance, spill control and safety system design. Its engineering staff are active in national and international standards development related to the storage, transportation and use of hydrogen.

Much of TISEC's unique expertise in hydrogen is captured in the Sourcebook for Hydrogen Applications, a comprehensive reference volume which is published on CD-ROM with the endorsement of Natural Resources Canada and the U.S. Department of Energy. This manual has become a benchmark information source for guidelines on the safe design and operation of hydrogen systems.

Xantrex Technology Inc.

Xantrex Technology, a private company, is a world-leading developer and manufacturer of advanced power electronics and controls with products from 50 watts to 1 megawatt. The company holds leading positions in test & measurement, consumer, mobile, buck-up, and distributed residential and industrial markets.

Xantrex's power electronics products convert raw electrical power from an energy source into high quality usable electrical power that meets user needs. The company's advances in power electronics are resulting in smaller, lighter, smarter, highly efficient and reliable systems that are a key enabling technology for its existing markets, as well as for emerging markets in wind, solar, advanced batteries, flywheel, microturbines, fuel cells and buck-up power. The company's products are sold under the Trace, Statpower, Heart, and Xantrex brands to diversified industry leaders.

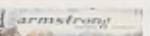
XCELLSIS FUEL CELL ENGINES INC.

XCELLSIS develops and manufactures hydrogen and methanol-fuelled fuel cell engines for the heavy- and light-duty transportation industry worldwide. There are facilities in Canada, Germany and the United States to reflect this international nature. XCELLSIS combines its expertise in fuel cell engines with Ballard Power System's proton exchange membrane (PEM) fuel cells to provide a complete product solution for environmentally friendly vehicles.

At the 2000 California Fuel Cell Partnership (CaFCP) grand opening ceremony in Sacramento, 7 of the 12 vehicles featured XCELLSIS fuel cell engines. The hydrogen-fuelled Phase 4 ZEBus (zero emission bus) was the first demonstration vehicle to be delivered to the CaFCP for a one-year testing program with SunLine Transit in California. Starting in early 2003, XCELLSIS Phase 5 heavy-duty fuel cell engines will be in operation in 30 buses in 10 European cities. XCELLSIS has also delivered a hydrogen fuel cell engine for Ford Motor Company's P2000 vehicle.



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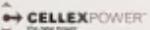
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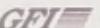
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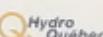
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